THE APPLICATION OF A DECISION MODEL IN THE MANAGEMENT OF RAW MATERIAL COSTS

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ABSTRACT

The management of raw material costs is of most importance, especially when it represents a considerable part of the industrial costs, when the price of raw materials is very volatile and the acquisition of raw materials has operational and strategic implications. However, most companies do not support the purchasing process of raw materials with models and procedures properly structured. Thus, supplier selection, the timing of the acquisition, and the quantity and allowable price of raw material ask for appropriate decision models which support a better cost management of raw material.

In this paper the main focus is to explain the developed method used to identify the best conditions for the acquisition of raw materials. The problem was to analyze several criteria such as: price, delivery time, credit line and how much time is needed for the delivery of raw materials, considering some suppliers. As the solutions needs to be sustained by a mathematical method including future choices, the development requires cooperation between the researcher and the actors involved in searching the solutions.

Based on an approach that combines decision trees, developed using *Precision Tree* software, and multicriteria models, the method, validated and tested, allows the decision maker to consider various criteria for selecting a supplier. The use of the decision tree developed turned possible to determine the supplier who offers the best overall expected value.

The model developed in Flexus S.A. gained wide acceptance by the managers and it is used to make procurement decisions of raw materials for its agility and easy understanding. Furthermore, the application of the model allowed Flexus S.A. to initiate trade relations with suppliers who had not been previously considered. This change allowed the company to increase responsiveness to customer needs.

INTRODUCTION

The management of costs with Raw Materials (hereinafter referred to as RM) is an activity of great importance in manufacturing. The acquisition and selection of suppliers has proved to be an important issue in several companies (Alencar et al., 2007). Porter (1980) analyzed the impact of the procurement function in business strategy and defining strategic objectives. Traditionally, companies have supported the process of buying RM based on tacit knowledge and due to the "sensitivity" of decision-makers. When RM costs represent a considerable part of the cost of industrial products, when the price of RM is very volatile and when decisions in terms of time of purchase, quantity and price of RM have operational and strategic implications, decisions relating to the acquisition of RM can lead to (significant) economic benefits for the company or (significant) losses due to unmet needs of RM or due to its acquisition at higher prices.

PROBLEM DESCRIPTION

The issue of acquisition of RM has been the subject of study by several researchers. The stock has the basic function, according to Carravilla (1997), to provide an immediate response to demand. Sometimes the demand will be greater than the supply, but there are other times when the supply is greater than demand and in both situations the stock of a company will be used as a time buffer between new RM entries and the final product outputs, but always in function of the RM replacement time so as to avoid long breaks. Deciding on the amount to acquire, the more accurate acquisition time as well as an efficient way to management stocks can be of great importance to companies in order to achieve lower costs. However, the importance of choosing a good supplier can never be determined only by the price at which he offers the product, since the cheapest supplier may not be the one that has the lowest price of RM.

Several researchers have tried to find a pattern for the rise and fall of the price of these materials on world markets, and the conclusion is that there are super cycles prices. Jerret and Cuddington (2008) (Figure 1) conducted several studies on the fluctuation of prices and introduced a standard for its evolution.

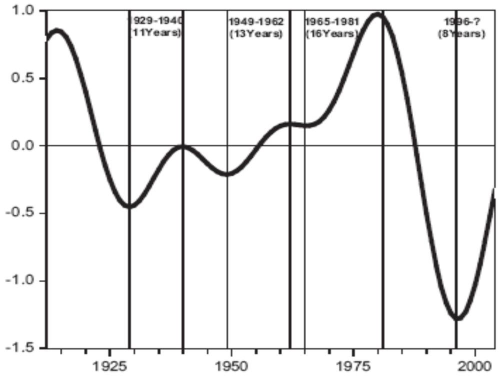

Figure 1 – Fluctuations in metal prices (Jerret and Cuddington, 2008)

In many cases the RM is purchased in large quantities representing very high costs. The question is may it be purchased at market opportunities and therefore at lower prices? The sectors of construction and the automotive industry account for a large part of the steel consumption in the world. However, the construction is the target market of steel with lower specificities, while the automotive sector seeks to permanently achieve the lowest possible weight and best mechanical characteristics. These two sectors of activity are preponderant in the steel price fluctuations in the world. In this sense, obtaining an in-depth knowledge of the RM, particularly the evolution of RM prices used gives a competitive advantage to companies that deal with these materials.

When we face a problem and we need to overcome it, we become decision makers and the information that we collect is an aid to better understand the context in order to develop and reach the best decisions. A decision model aims to assist the decision maker in the decision process, exposing clearly the elements of the decision and allowing to articulate its preferences, in the presence of uncertainties, allowing to make decisions more coherent with his own interests (Clemen and Reilly, 2001). If a problem has more than one possible solution, we are facing a decision problem which can be simple or complex, depending on the amount of information to be analyzed. The management of RM costs includes deciding on the quantities to purchase, purchase prices, costs and transport times, synchronization with the production and the market, adjusting to the conditions and financial constraints, among other things, therefore it can be seen as a complex problem.

The company studied (Manufacturas Mechanical Flexus SA) is a typical example of a company with a supply policy with reduced stock rotation. In these cases, the need to have permanently available RM results from the huge fluctuation of prices and long delivery times. These conditions lead to a long-term RM acquisition policy based on large quantities. In this context, the company was faced with an urgent need to properly manage the cost of RM which depend on several variables: Unit cost of RM, acquisition cost for different suppliers, RM quantity necessary for the production of end products and intermediates, the acquisition of RM in rolls or strips, among other things.

The main goal of any business is to have profit and to achieve it in a steadily increasing manner. For this purpose to be achieved the company should work with the best prices with the most appropriate quality and with suppliers who can better meet their needs. So, the choice of suppliers has additional importance. The supplier selection policy, the costs associated with purchasing procedures and stock policy deserve to be object of study and reflection. Despite the cost management with suppliers being quite complex, involving various aspects, there are several approaches that can be implemented, for example, the Total Cost of Ownership (TCO). TCO aims to estimate clearly the direct and indirect costs associated with a process of acquiring a particular good or service (Degraeve et al., 2005). According to Bremen et al. (2007) research should be focused on policies for selection of the best suppliers, conducting assessments on the level of timely deliveries, product quality and risk management, and the supply chain, given the capital tie and the level of risk, due to the environment politicy of the respective country. Ultimately it is a whole new way of looking at the problem, "Detailed information about the cost of outsourcing makes it possible to choose low cost suppliers rather than low price suppliers" Bremen et al. (2007, p.262).

DECISION MAKING

The uni-criteria decision models are used to optimize one variable of the problem, such as maximizing profit or minimizing cost. Multi-criteria decision models allow to consider more than one criterion in obtaining the solution. In this second type of models, normally an optimal solution cannot be obtained for all criteria simultaneously, it is necessary to find a compromise solution. The use of uni-criteria models with decision trees allows to include uncertainties, using probabilities, and helps to build the model through a systematic process. Figure 2 shows an example of a decision tree, where after the initial decision, there are chance nodes with the probability of each outcome. Other decisions and uncertainties are also represented to illustrate the sequencial structure decision making process that can be represented.

The decision support models are developed using a constructivist paradigm where the actors of the decision process discover together the problem in analysis and a model is thus obtained, hopefully the one that best meets the interests of the group. The study of a problem within the MCDA approach (Multi Criteria Decision Analysis) includes three phases: structuring, evaluation and recommendations, which continuously interact. When the problem involves the consideration of several criteria, the model becames more complex requiring the use of multi-criteria decision models. The analisys should focus on:

- Identifying the decision alternatives;

• Checking the accuracy of the restrictions;
• Identifying evaluation criteria.

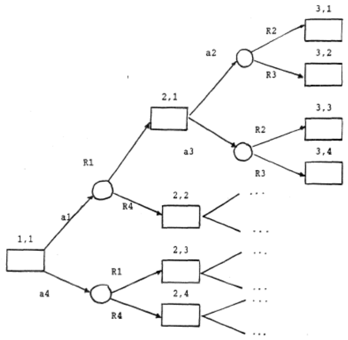

Figure 2 – Example decision tree chain decisions (taken from Whit,1969)

These three points become essential and are the starting point to a more accurate decision making process (Tereso, 2011). The need to use MCDA methods should be justified by the need to have an accurate assessment, taking into account several criteria of the suppliers. The literature review enabled to find a simple way to consider various criteria together with decision trees (Chen et al., 2011). Using a simple additive weigting function allows to translate all criteria into a global value. By using criteria weights and maximization or minimization functions one can classify each supplier in the selection process.
The method used to solve this problem is referred to as Simple Additive Weigthing (SAW) method (Tereso, 2011). This is a method of wide use where the final score is the result of the weighted sum of various criteria, using for such a common numerical scale. Thus the general formula for the calculation of the scores in this method is:

$$V_i = \sum_{j=1}^{n} w_j r_{ij}$$

$V_i -$ overall score for option i;
$w_j -$ weight of criteria j;
$r_{ij} -$ score of option i on criterion j.

The score used for each criterion under analysis will be used to evaluate the weighted sum on the formula. To compare the alternatives it is necessary to convert the different values for the various criteria on a common scale, for example on a scale from 0 to 10. This may be done using the formulas (1) or (2) when the objective is to maximize the criterion or minimize the criterion, respectively.

$$(1)\ V(Objectiv = Máx) = \frac{(x - Min)}{(Máx - Min)}$$

$$(2)\ V(Objectiv = Min) = \frac{(Máx - X)}{(Máx - Min)}$$

DECISION MODEL DEVELOPED

Commodities although quite uniform across different global economies, always represent volumes of substantial business in each of them. The development of a model to support the decision on acquisition of RM can be similar for different companies but has to be adapted to each case. In the case studied, the decision maker will evaluate four items from different suppliers, the decision criteria:

- Total cost;
- Delivery time;
- Payment term;
- Credit line.

In developing the decision tree model it is necessary to determine which are the decisions, which are the chances, and the consequences of the selection of each supplier, in order to maximize the overall result of each decision alternative.
The decisions considered in the model were:

- D1 - Analyze the market;
- D2 - Service centers selection;
- D3 – Supplier selection;
- D4 - Great provider selection.

At these decision nodes underlie the alternatives shown in table 1, depending on the supplier selected (F), this is, the end result of all the calculations in the model.

Table 1 – Decision nodes and subsequent actions

D1	D2	D3	D4
a1: Analyze the market	a2: F7	a6: F1	a19: F2
	a3: F8	a7: F6	a20: F3
	a4: F11	a8: F7	a21: F5
	a5: F18	a9: F8	a22: F12
		a10: F9	a23: F13
		a11: F10	a24: F14
		a12: F11	a25: F15
		a13: F12	a26: F21
		a14: F13	a27: F23
		a15: F17	a28: F24
		a16: F18	
		a17: F20	
		a18: F 22	

The chance nodes considered in the model were:

- I1 - Market Position;
- I2 - Urgent;

Table 2 – Chance nodes and results

I1 : Market position	I2 : Urgente
R1 : Market High (Alta)	R4: Yes
R2: Stagnant market (Estagnado)	R5: No
R3: Falling market (Queda)	

Briefly the structure of the decision model created is present in Figure 3. Depending on the market conditions and urgency, the decisions may be different. Considering the decision criteria, for the different suppliers in the procurement process, the model indicates what is the best supplier.

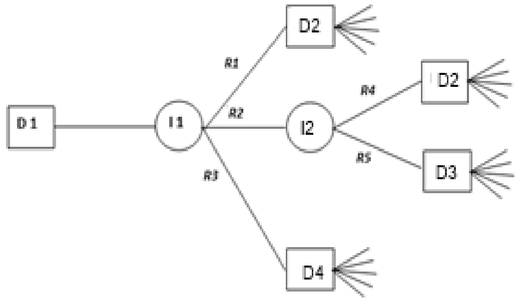

Figure 3 - Decision Structure

Some details about the implementation of the decision model will be explainded further in this chapter. The following criteria and objectives (minimize or maximize) were considered:

- Total cost (minimize);
- Delivery time (minimize);
- Payment term (maximize);
- Credit line (maximize).

The evaluation of the average cost (AC) is made on the basis of three types of material analysis and is subsequently used for the value of the total cost of the supplier considered, using for comparison the maximum and minimum values for each supplier. The AC of a supplier is evaluated as a weighted average according to the percentage of purchasing of each thickness E and product type (cold-rolled, F, pickled, Q, galvanized, Z), depending on total amount bought of each material.

$$\mathrm{AC}F = 2\% * E1F + 10\% * E2F + 30\% * E3F + 20\% * E4F + 10\% E5F + 25\% E6F + 3\% E7F$$

$$\mathrm{AC}Q = 30\% * E1Q + 2{,}5\% * E2Q + 35\% * E3Q + 20\% * E4Q + 2{,}5\% * E5Q + 10\% * E6Q$$

$$\mathrm{AC}Z = 10\% * E1Z + 7{,}5\% * E2Z + 5\% * E3Z + 2\% * E4Z + 15\% * E5Z + 15\% E6Z + 10{,}5\% * E7Z + 20\% * E8Z5 + 5\% * E9Z + 10\% * E10Z$$

To agregate monetary criteria with delivery time, line of credit and payment terms needs scale convertion. The global scale used was a scale from 0 to 100 (0 being the worst and 100 the best).

After completion of the AC of each supplier it becomes necessary to compare among all evaluated to determine its value for each criterion. Considering that the objective is to minimize cost, the function used to convert the cost values into the scale 0 to 100 was the following:

$$V(Total\ cost) = \frac{(Cmáx - C) * 100}{(Cmáx - Cmin)}$$

$Cmáx$**.** – Maximum total cost;
C – Total cost of the supplier under evaluation;
$Cmin$ – Minimum total cost.

It is necessary to convert the delivery time of each supplier as well.

$$V\ (Delivery\ time) = \frac{(Pmax - P) * 100}{(Pmax - Pmin)}$$

$Pmax$ – Longer delivery time;
P – Supplier delivery time under evaluation;
$Pmin$ – Shorter delivery time.

The assessment is carried out in days to delivery of RM and can determine which vendor has the best delivery time, i.e., which will deliver the RM as soon as possible, and as in previous criterion, the goal is to minimize this evaluation factor.

The third criterion to be compared is the payment deadline. In contrast to the previous two criteria, the payment period will be better the wider it is. In this case the used calculation function was the following:

$$V\ (Payment\ Term\ ) = \frac{(Pp - Ppmin) * 100}{(Ppmáx - Ppmin)}$$

Pp – Supplier paymet term that is being evaluated;
$Ppmin$ – Minimum payment period;
$Ppmáx$ – Maximum payment period.

The fourth and last criterion to be evaluated was the line of credit that each supplier offers to the company to make their purchases.

$$V\ (Credit\ Line) = \frac{(L - Lmin) * 100}{(Lmáx - Lmin)}$$

L – Credit line provided by the supplier being evaluated;
$Lmin$ – Minimum credit line of all suppliers;
$Lmáx$– Maximum credit line of all suppliers.

The criterion credit line calculated in euros (€) assumes that the best supplier is the one that provided the largest sum of money to carry out acquisitions. Upon acquisition of RM, the company has the possibility of using various forms of payment, among them are:

- Line of credit granted by the supplier to the enterprise;

- Use of a financial loan from the national and international banking;
- Opening a letter of credit using the credit insurers;
- Join Venture, above, which is the remotest chance and with greater difficulty.

Choosing the second or third option will incur financial costs than those charged on the price of RM assigned by the supplier, such as interest on bank loan or costs for opening the letter of credit. These costs should be a derogatory factor in choosing a supplier and therefore the more a supplier give credit for your account to the company, the more favorable it becomes to acquire.

The problem analysis was then moduled using a decision tree. The computer tool which formed the basis for the implementation of the model was the Precision Tree, an add-in to Microsoft Office Excel, from Palisade Decision Tools. The first decision the decision maker faces is to analyze the market, allowing the determination of the market position (Figure 4).

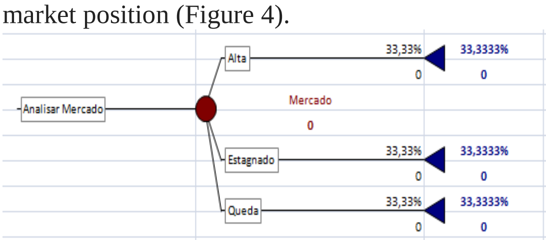

Figure 4 – D1 decision node - Analyse the market

The second decision node built in the decision tree, was the Service Center (D2). It refers to suppliers that have a shorter delivery time than others in comparison.

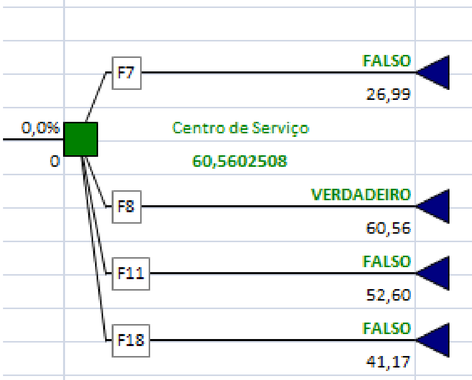

Figure 5 – D2 decision node service center

This decision node (Figure 5) has four decision alternatives F7, F8, F11 or F18. These decision alternatives are subject to evaluation by the multi-criteria model developed, complementary to the decision tree using the SAW method, that evaluates each supplier using the four criteria defined, and thus calculate an overall value for each supplier, which is after used in the decision tree. In decision node D2 there are only four of the twenty-four possible suppliers, the alternatives that make sense in this case. The D3 decision node called Supplier is the one with the highest number of decision alternatives, in this case 13 possible suppliers. These decision alternatives are presented in this node because the delivery time of these suppliers is suitable to the case. The last decision node built, D4 Great Provider is regarding suppliers that, because of their characteristics, can sell large quantities of product at very competitive prices, but have a longer delivery time.
The construction of decision trees includes the existence of alternatives that after the selection result in consequences, but uncertainty in the situation also needs to be represented. The elaborate decision model used two chance nodes.
The first chance node (Figure 6) was constructed to represent the uncertainty about the position (state) of the market.

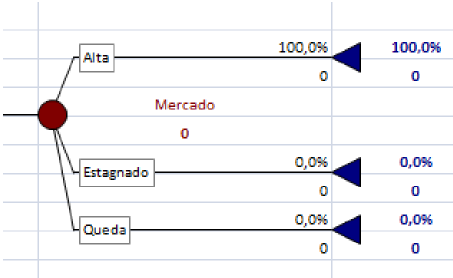

Figure 6 – Chance node I1 - Market Position

The second chance node (Figure 7), represents the urgency or not of a purchase and is linked to Table 4, where the decision maker indicates his opinion and the model in Precision Tree will indicate which supplier to choose (with the greatest EMV - Expected Monetary Value).

Table 3 – Emergency RM

	Yes	No
Emergency	0%	100%

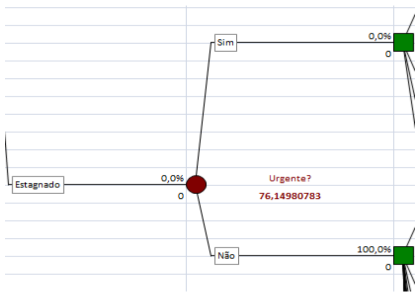

Figure 7 – Chance node I2 - Emergency

After the determination of decision nodes and uncertainty nodes, we can see the complete model created in Precision Tree (Figure 8).

RESULTS

Setting the individually evaluation of each of the four criteria means, by itself, to obtain an ordering between the suppliers, for each criteria. This achievement is not sufficient to obtain the best selection considering all the criteria because they do not all have the same importance to the act of purchasing. To use the SAW method on the developed model, using the above formulas, was necessary to give weights to the criteria, as follows:

- $V\ (Total\ Cost)$ – it was assigned the weight of 75% to the supplier total cost criteria since this was considered the most important one for the determination of the supplier;

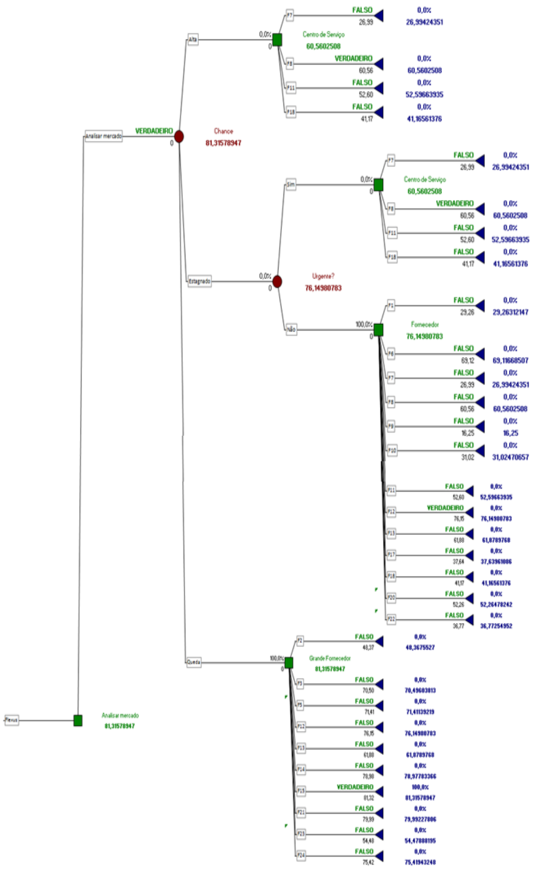

Figure 8 - Model in Precision Tree

- $V\ (Delivery\ time)$ – it was assigned the weight of 15% to the supplier's delivery time criterion since the delivery as soon as possible can mean an absence stop the production process due to lack of RM, representing the existence of stock is a real saving;
- $V\ (Term\ of\ payment)$ – it was assigned the weight of 2.5% to the criteria term of payment provided by the supplier since in addition to the above criteria, the payment period is also an important evaluation criterion. But the longer the term, the more advantage will the company have;
- $V\ (Credit\ line)$ – it was assigned the weight of 7.5% to the criteria credit line provided by the supplier, since the difficulties of Portuguese companies are known worldwide, therefore it is important obtain credit from a distinct entity than a bank.

The Global Value of each supplier is the result of all previous assessments. To calculate the Overall Value of a vendor we used the following equation:

$$\begin{aligned}\textbf{Global Value} = {} & 75\% * V(Total\ Cost) + 15\% \\ & * V(Delivery\ time) + 2{,}5\% \\ & * V(Term\ of\ payment) + 7{,}5\% \\ & * V(Credit\ line)\end{aligned}$$

To determine the supplier selection requires the application of the weights on the criteria used in the Global Value function.

In developing the model, 24 possible suppliers were considered for analysis, among which there are the so-called service centers, which, for reasons of responsiveness and availability, can be considered both at the time of emergency purchase as normal acquisition time with bull market. This paper shows the creation and use of a model that allows submitting a market analysis and decide the supplier, in face of uncertainty.

Table 4 – Solution obtained

Decision	Optimal Choice	Arrival Probability	Benefit of Correct Choice
'Analisar mercado' (B103)	Analisar mercado	100,0000%	0
'Centro de Serviço' (D31)	F8	33,3333%	33,56600729
'Fornecedor' (E55)	F12	33,3333%	59,89980783
'Grande Fornecedor' (D83)	F15	33,3333%	32,94823678

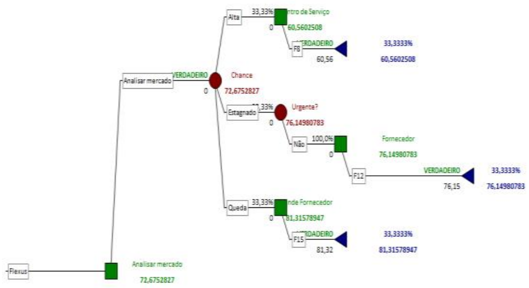

Figure 3 – Optimal decision tree in a full market uncertainty

The optimal choice was to select supplier F8, F12 ou F15, depending on the market conditions. The EMV obtained was 72,67 on a scale 0 to 100 (see figure 9).

CONCLUSIONS

Because there are several criteria to be analyzed, this problem was classified as a multicriteria problem. It was necessary to reduce the criteria subject to review and influence in decision-making to the most important such as: total cost, delivery time, term of payment and credit line available. The decision model built using the values of the multi-criteria decision model. A scale of values from 0 to 100 maximizing the overall value of each supplier using the SAW method.

Despite the simplicity of this decision support model, using it allowed the company to speed up the procedure for evaluating the different suppliers for the acquisition of RM, thus revealing as an asset to the company in terms of data processing and aid to the purchasing decision on the supplier selection problem. It because more agile and competitive in a demanding global market. In the future users will be able to add decision criteria and applications can be developed on which to make the connection between the developed model and stock control company software.

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